IN SITU NANOINDENTATION OF ULTRANANOCRYSTALLINE DIAMOND AND AMORPHOUS DIAMOND THIN FILM COATINGS

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Ultrananocystalline diamond (UNCD) and amorphous diamond (a-D) thin films have great potential to be used as surface coatings and as structural layers to fabricate microelectromechanical systems (MEMS) devices in general and biodevices in particular due to their superior mechanical properties, biocompatibility and excellent conformality in the case of UNCD films. Nanoindentation is accepted as the most useful technique to study localized mechanical phenomena in materials of thin film form. However, the mechanisms of deformation can only be inferred from the load-displacement data obtained during a typical instrumented nanoindentation test.

In order to elucidate the underlying physics of the mechanical deformation process in these materials, we have utilized the technique of in-situ nanoindentation in a transmission electron microscope (TEM). With this technique, a voltage-actuated piezoceramic tube is used to position a sharp diamond in-plane with the edge of an electron transparent sample. The tip is driven into the material in order to induce deformation and the corresponding response is observed in real time and at high spatial resolution.

In this presentation, we will discuss our observations of the indentation of both UNCD and a-D thin films deposited onto bulk micromachined silicon substrates. The use of micromachined substrates to provide electron-transparent samples is critically necessary for the evaluation of these diamond films, since ion-milling converts sp^3-bonded carbon to sp^2-bonded. Both thin films show an ideal combination of strength and compliance during elastic loading. In each case, we find that the high stresses induced by the indenter are effectively transferred to the substrate, resulting in room temperature dislocation plasiticity in the underlying silicon substrate (Figure 1). Figure 2 presents data from instrumented indentation tests of these same films. A pop-in event is observed at a displacement of approximately 50 – 60 nm indentation depth, corresponding to the depth at which dislocation plasticity is induced.). Upon removal of the indenter, no permanent deformation or large-scale fracture of the films is observed, indicating that both a-D and UNCD are particularly effective as ‘hard’ coatings.

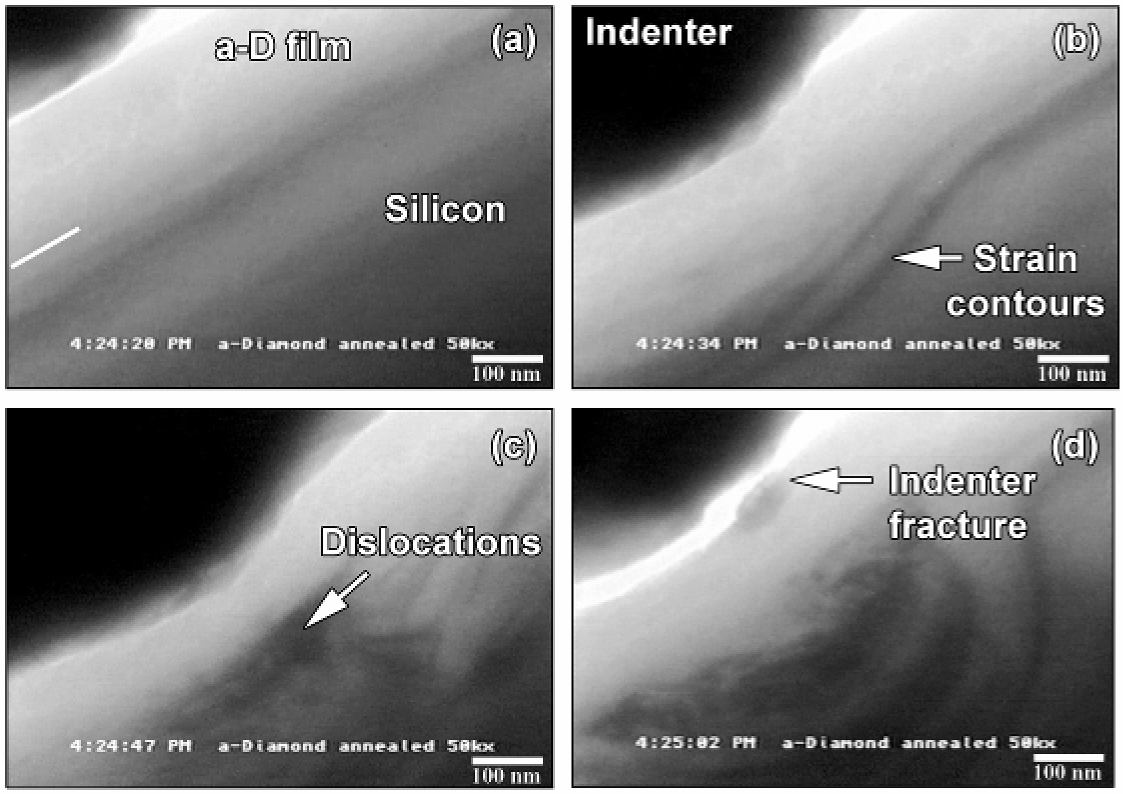

Figure* 1. *(a) Cross section TEM image of an amorphous diamond thin film coating on silicon, prior to indentation (b) initial elastic indentation (c) dislocation plasticity induced in the underlying silicon substrate (d) permanent deformation in the substrate following removal of the indenter tip.

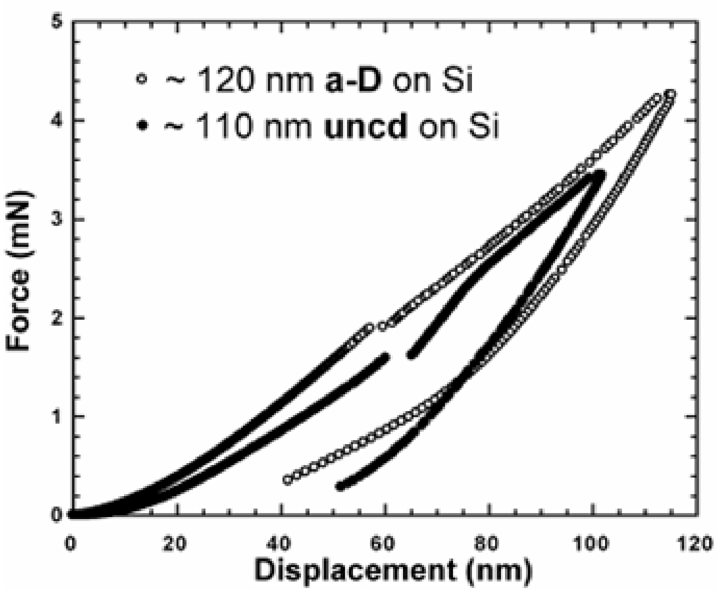

Figure* 2. *Load-displacement data from instrumented indetation tests of both a-D and UNCD films on silicon